AN 11-METER DEPLOYABLE TRUSS FOR THE SEASAT RADAR ANTENNA

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ABSTRACT

The recently developed Extendable Support Structure is a folding three-dimensional truss and tripod assembly which deploys the SEASAT Synthetic Aperture Radar Antenna. The folding structure with the antenna panels and rf components stows in an 8.5-inch-thick package. Upon deployment, the structure produced is a flat and rigid support for the antenna.

INTRODUCTION

The Extendable Support Structure (ESS) is a 35-foot (10.7-meter) deployable truss developed by Astro Research Corporation, Santa Barbara, California. The structure provides launch packaging and on-orbit extension for the Synthetic Aperture Radar (SAR) Antenna developed by Ball Brothers Research Corporation, Boulder, Colorado, for the SEASAT Global Ocean-Survey Satellite.

Scheduled to be launched during the spring of 1978 from Vandenberg Air Force Base, California, the SEASAT Satellite will be inserted into a circular 430-mile near-polar orbit by an Atlas/Agena Booster system. The satellite will continuously circle the globe, covering 95 percent of the earth's ocean area, every 36 hours.

After ascent to orbit, upon command, the folded and stowed SAR Antenna will be deployed from the SEASAT Satellite and extended, via the ESS, into a planar array 35 by 7 feet. The array will provide valuable and precise realtime all-weather radar imagery of ocean topography such as wave patterns, ice heads, icebergs, coastal erosion and environmental management features. The on-orbit configuration of the SAR Antenna and Satellite is shown in Figure 1.

The ESS furnishes a mounting bed for the eight honeycomb panels, which upon extension becomes the planar array of the SAR Antenna.

The ESS provides the strength and rigidity necessary to withstand the launch vehicle environments. Upon extension, it supports the antenna panels to maintain precise flatness, including mechanical alignments and thermal distortions, throughout the mission-orbit environment.

DESIGN REQUIREMENTS

The ESS was challenged by several major design requirements:

1. pointing of the array's planar surface to ±0.2 degree,
2. repeatability of the array's pointing to ±0.1 degree,
3. fundamental resonant frequency (stowed ≥10 Hz and extended ≥0.5 Hz),
4. weight less than 77 pounds,
5. planar flatness within ±0.25 inch over the orbit temperature ranges of 200 to -250°F, and
6. fourteen-month program from start of development to delivery of the flight ESS, which meant the development unit was to become the qualified flight unit.

Envelope

The envelope for packaging the SAR Antenna was defined by the volumetric availability of the SEASAT Satellite sensor module. The dimensions of this envelope are 101.5 by 64.0 inches with a packaged thickness of 8.5 inches. Thus, the planar array length of 35 feet was required to be folded and restrained for launch within the 8.5-inch dimension. This alone was a major design parameter, in that the total thickness of the eight antenna panels accounted for 3.66 inches, leaving only 4.84 inches for the development of a three-dimensional rigid and stable folding truss and launch fittings.

Truss

The ESS has to support the 130-pound weight of the eight antenna panels and associated rf system for launch. To achieve this goal, the truss work of the ESS provided mounting hardware for the panels. To withstand the 8-g axial launch-vehicle acceleration, the truss incorporated nesting and interlocking structural features so that panel and truss loads could be transferred to the spacecraft structure by three launch restraint-arm mechanisms. The interlocking features of the truss consists of cups and cones and key-type fittings which engage each other in the folded configuration and release one another during the truss extension. The stacks of cups and cones are clamped and preloaded by the launch restraint-arm mechanisms. Three load paths are employed, one at the apex of the truss and two at the hinge line of the truss (Figure 2). Thus upon the satellite's obtaining a ready-for-SAR deployment status, the launch restraint arms are pyrotechnically released and the ESS freed for deployment maneuvers and extension.

Deployment

The envelope allocation also required the folded and stowed package to be rotated out-board of the spacecraft in two 90-degree maneuvers. These maneuvers were required to achieve a position for array extension which would result in the long axis of the planar array being aligned with the velocity vector of the spacecraft. In addition, the normal of the array's planar surface was to be pointed 20 degrees up from nadir, thus requiring the ESS to pitch-up the antenna plane during extension of the array.

This deployment sequence was efficiently implemented by a BIAX mechanism, developed by Lockheed Missiles and Space Company, which performed the two 90-degree maneuvers (Figure 3). The ESS performs the array extension concurrent with the 20-degree pitch-up rotation.

Upon completion of the 7-minute powered extension, the ESS truss forms a three-dimensional structure providing a flat array surface (within ±0.090 inch to a least square best-fit plane).

DETAILED DESIGN DESCRIPTION

The ESS consists of a tripod assembly and a truss assembly. They are discussed separately in the following. Also, the design of important joints in the structure is described.

Tripod Assembly

The tripod is the single mounting of the deployed antenna to the spacecraft and controls the orientation of the truss during and upon extension. The tripod consists of two folding arms and a fixed brace mounted to a short box structure (Figure 4). The location of the pivots of the arms and the single pivot at the tip of the brace direct the motion of the truss from its flat package to its extended position. As the ESS unfolds, the orientation of the truss is rotated to the position 20 degrees from its initial packaged angle.

Deployment is controlled by the extension of a dc-motor-driven linear actuator. The actuator drives a central lever which has two ball-ended connecting rods joining it to the tripod arms. The arms are pulled to full deployment where spherical stops seat and provide support to the arms.

The arms and the nonrotating brace are titanium members with aluminum fittings in the arms. Titanium is used to minimize the effect of temperature changes on the pointing angle of the antenna.

Truss Assembly

The truss is made up of repeating frames and members which connect in seven types of joints. Along its long dimension are three longerons; two are tubular and the third is a flat bar (Figure 5). With the exception of the control linkage, each of the other members is tubular and connects the longerons. The control linkage is the second flat-bar linkage which mounts to the flat-bar longeron in seven places. The frames which lie in the plane on which the antenna panels are mounted consist of a section of the two tubular longerons, a perpendicular cross bar connecting them, and a diagonal. A vee-shaped, two-member frame connects the two tubular longerons to the single flat longeron, and two other straight members complete the truss.

The joints are designed such that the member axes intersect in the deployed truss. Each of the joints is pin-connected with dual tangs in each titanium fitting through which the pin passes. Special fittings were also bonded into the tubes where they cross, in the stowed position, to permit the flat package to be obtained.

The tubes and the flat bar are all graphite/epoxy composite. The fittings are bonded to the members with graphite/epoxy outside on the tube members and inside on the solid flat bar. The graphite/epoxy composite was chosen primarily for its low thermal-expansion properties. The composite members also provide a beneficial stiffness-to-weight ratio, but require the use of the titanium fittings to reduce thermally generated stresses in their attachment bond joints.

To synchronize the extension of the truss and assure full extension, two special types of joints were designed. These joints function to assist extension by torsion springs which drive to straighten the flat-bar longeron.

The synchronized joint connects two vee-shaped frames to the flat-bar longeron and control linkage (Figure 6). This joint utilizes a toggle linkage to control the spread of the vee-shaped frame in accordance with unfolding of the flat-bar longeron. The rotation of the central shaft of the joint drives opposing ball-ended linkages to deploy the frames. The stud which protrudes upward in the upper view of Figure 6 is located in two places along the apex of the truss where the tripod arms join the truss.

A spring-loaded toggle-type joint was designed into the flat-bar longeron hinges. To permit the longeron to fold 180 degrees, the hinge centerline is placed on the edge of the longeron as shown in Figure 7. The torsion spring on the hinge axis is greatly assisted toward the end of deployment by an "almost-over-center" latch which acts on the opposite edge of the hinge. The latch consists of two levers and a torsion spring and contributes approximately 12 in.-lbs of torque to close the longeron hinge at full deployment. This lever action multiplies the torque from the torsion spring so as to assure that the hinge will remain closed, even with 1-g loads, without requiring a lock.

FABRICATION AND TEST

The ESS has been integrated into the SAR System as shown in Figures 8 through 10. In these photographs, the thermal blankets and rf components are being installed and the assembly is mounted on a gravity-compensation fixture.

The weight of the ESS, consisting of the tripod and truss assembly, is 64 pounds. This is less than one-third the total antenna weight.

The deployed ESS produces a panel mounting surface which measures to be flat within ±0.09 inch peak from the least square best-fit plane. Extension of the structure and measurements of flatness were made with the ESS mounted on the gravity-compensation fixture.

The stowed natural frequency was tested with the panels, rf components, and launch restraint. The fundamental frequency was greater than 10 Hz. The deployed frequency was determined to be 0.9 Hz.

SEASAT PAPER NOTE

This work was performed for JPL, sponsored by NASA under contract NAS7-100. The folding truss concept was developed by Astro Research Corp. during internal proposal funding.

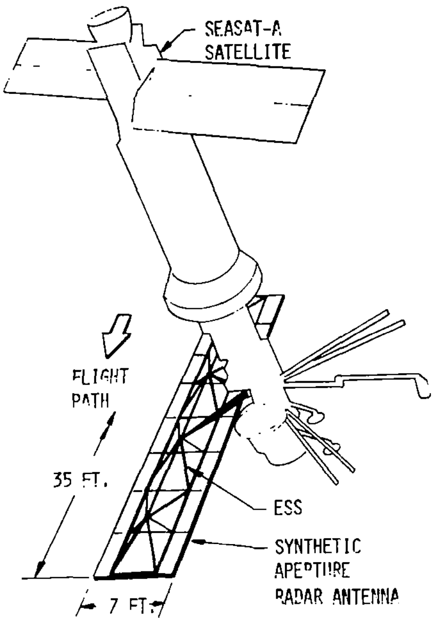

Fig. 1. Satellite Configuration.

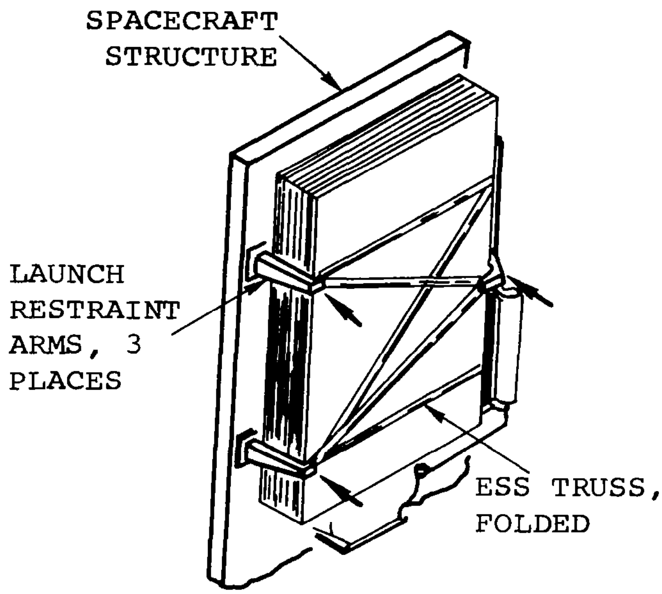

Fig. 2. Stowed Truss Load Paths.

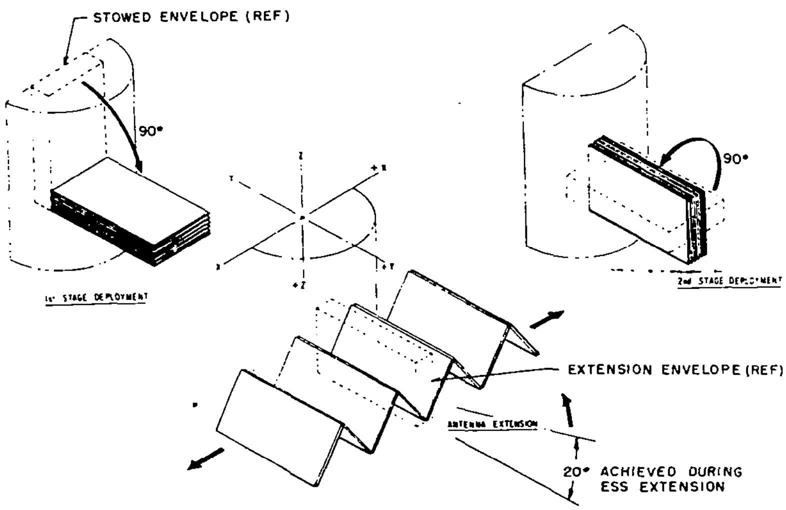

Fig. 3. Envelope Deployment Sequence.

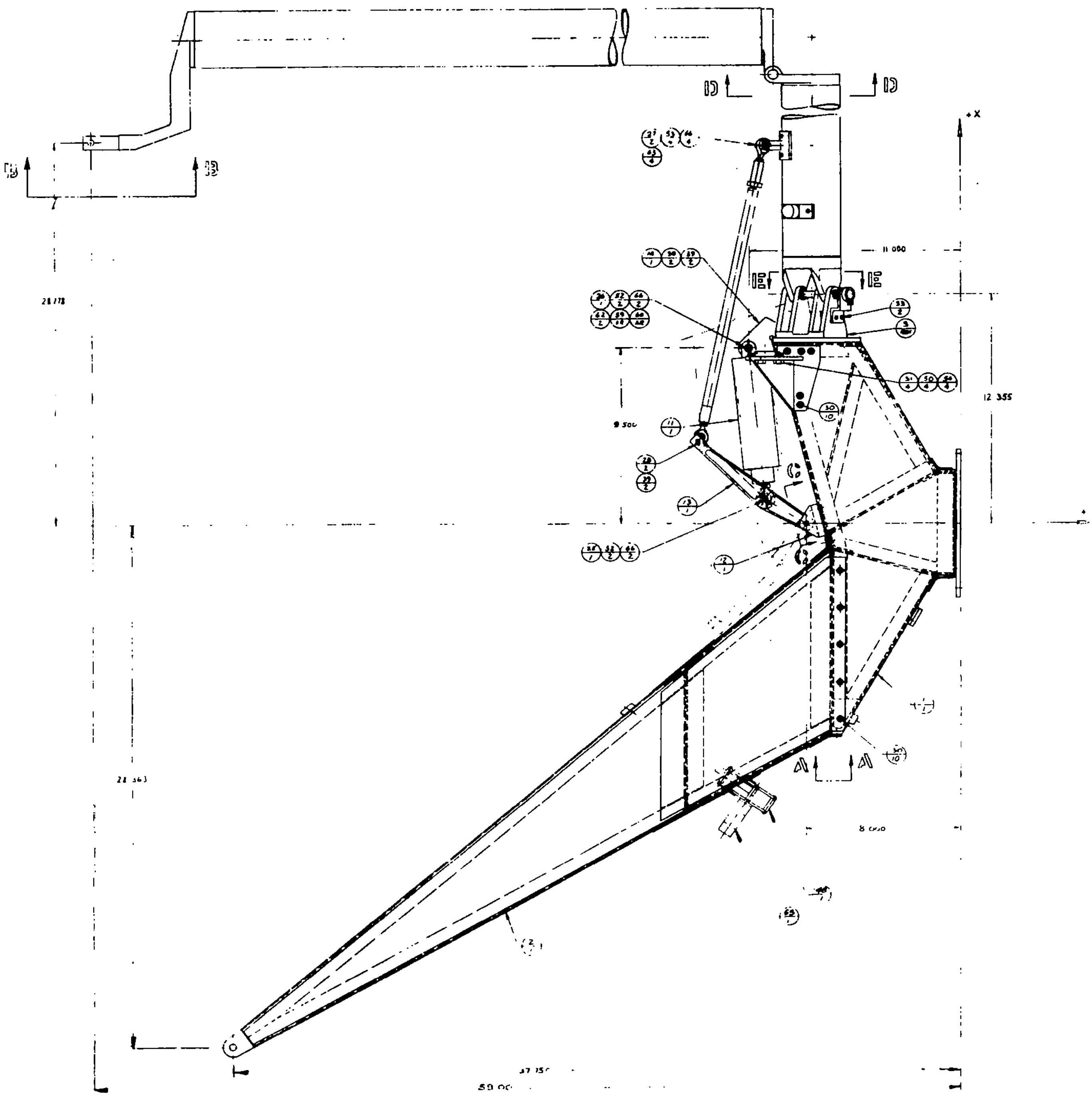

Fig. 4. Tripod Assembly.

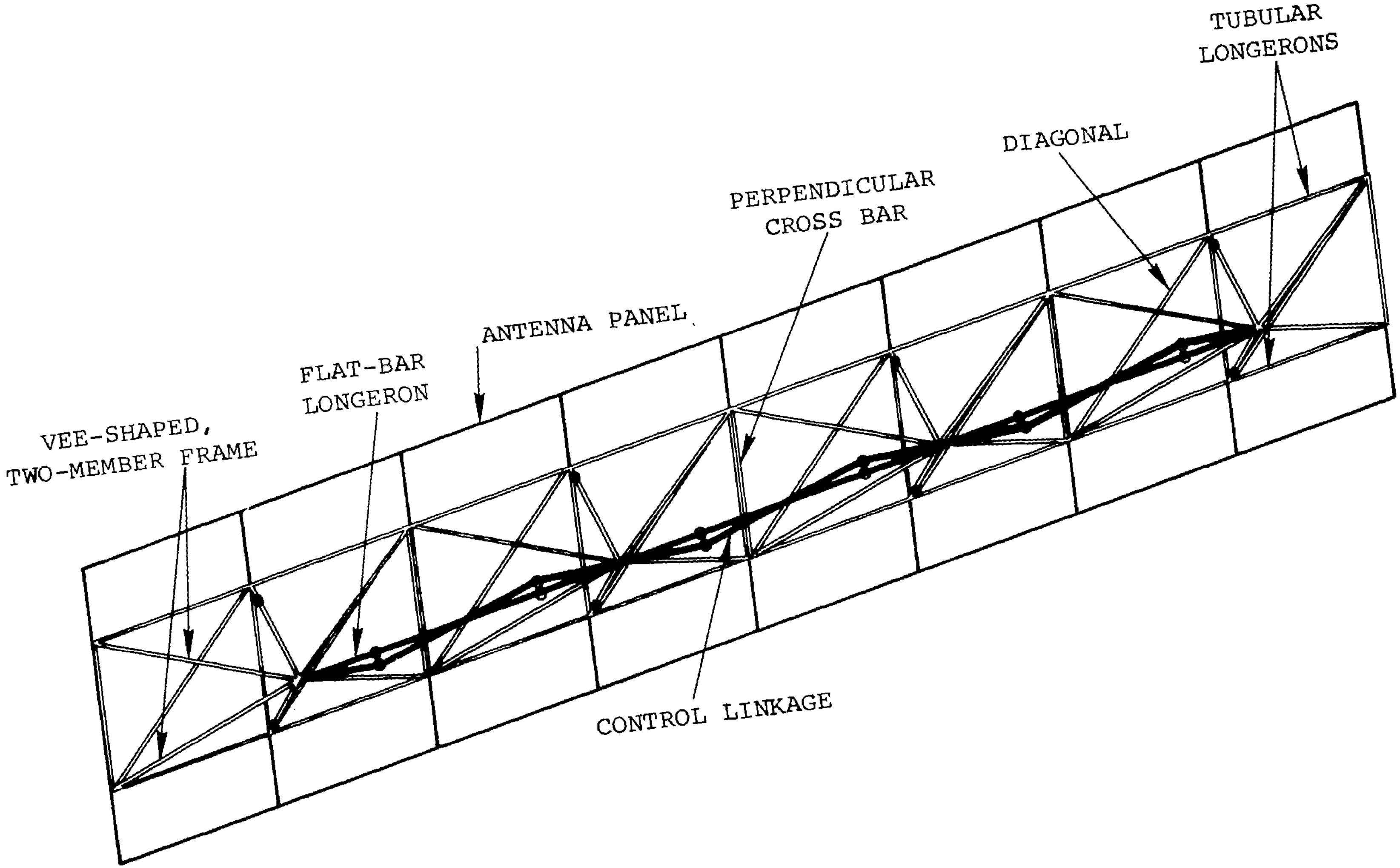

Fig. 5. Deployed ESS.

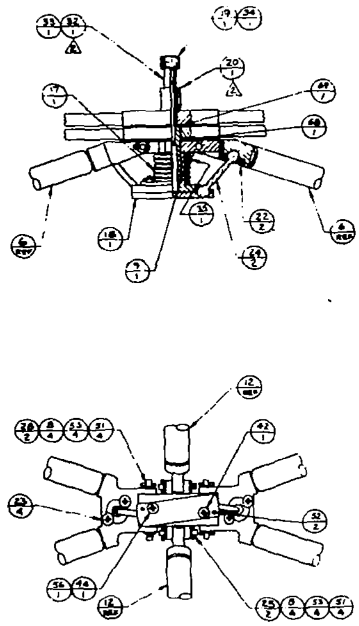

Fig. 6. Synchronized Joint.

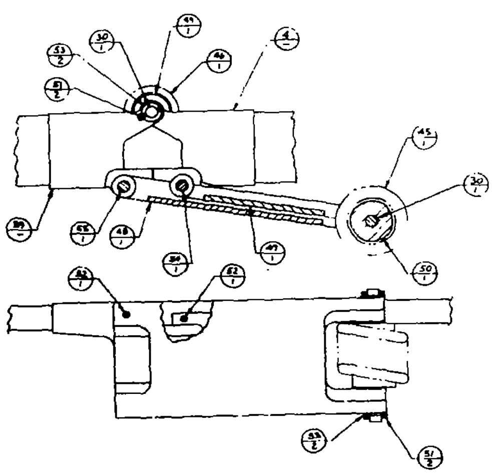

Fig. 7. Longeron Hinge.

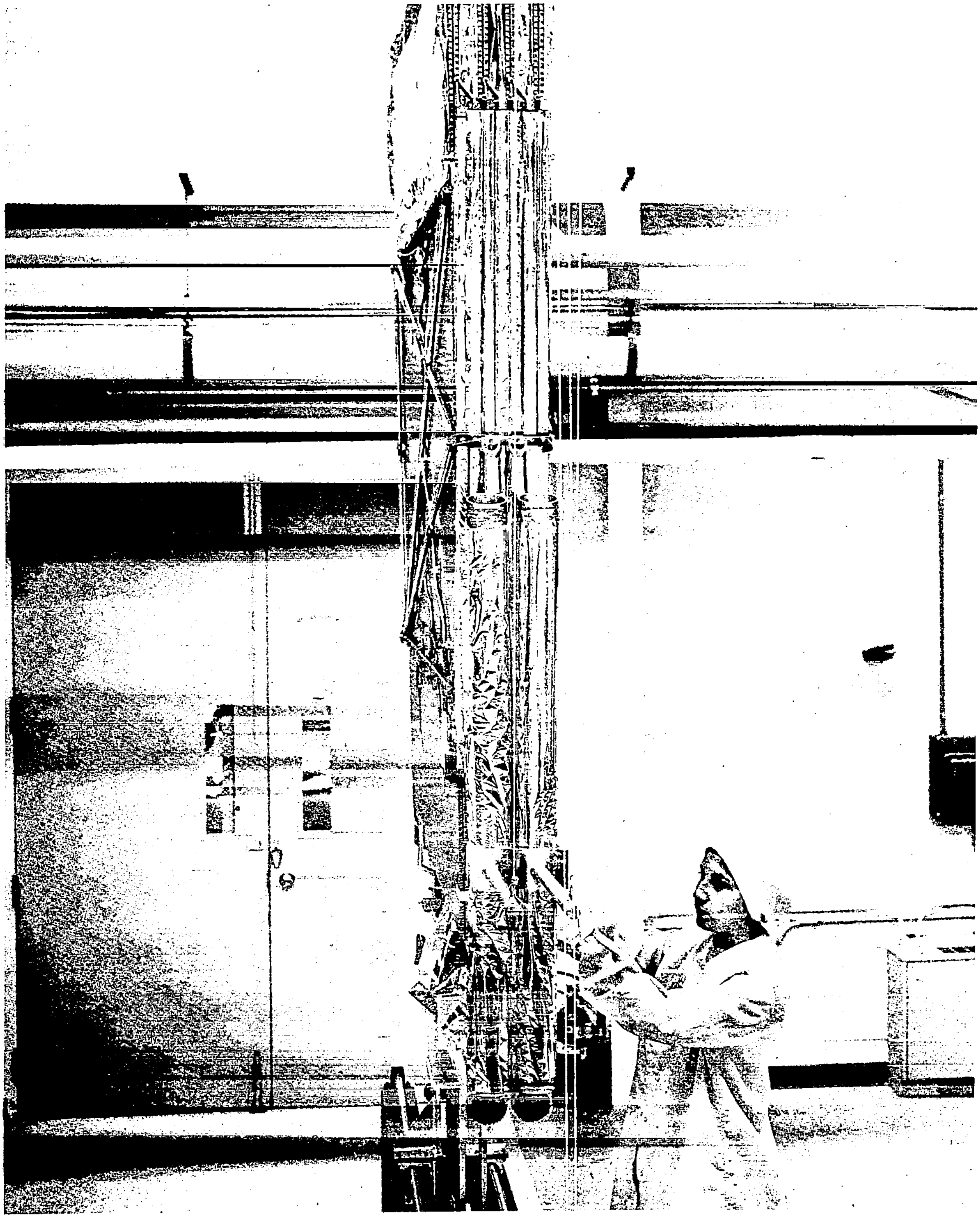

Fig. 8. SAR Stowed.

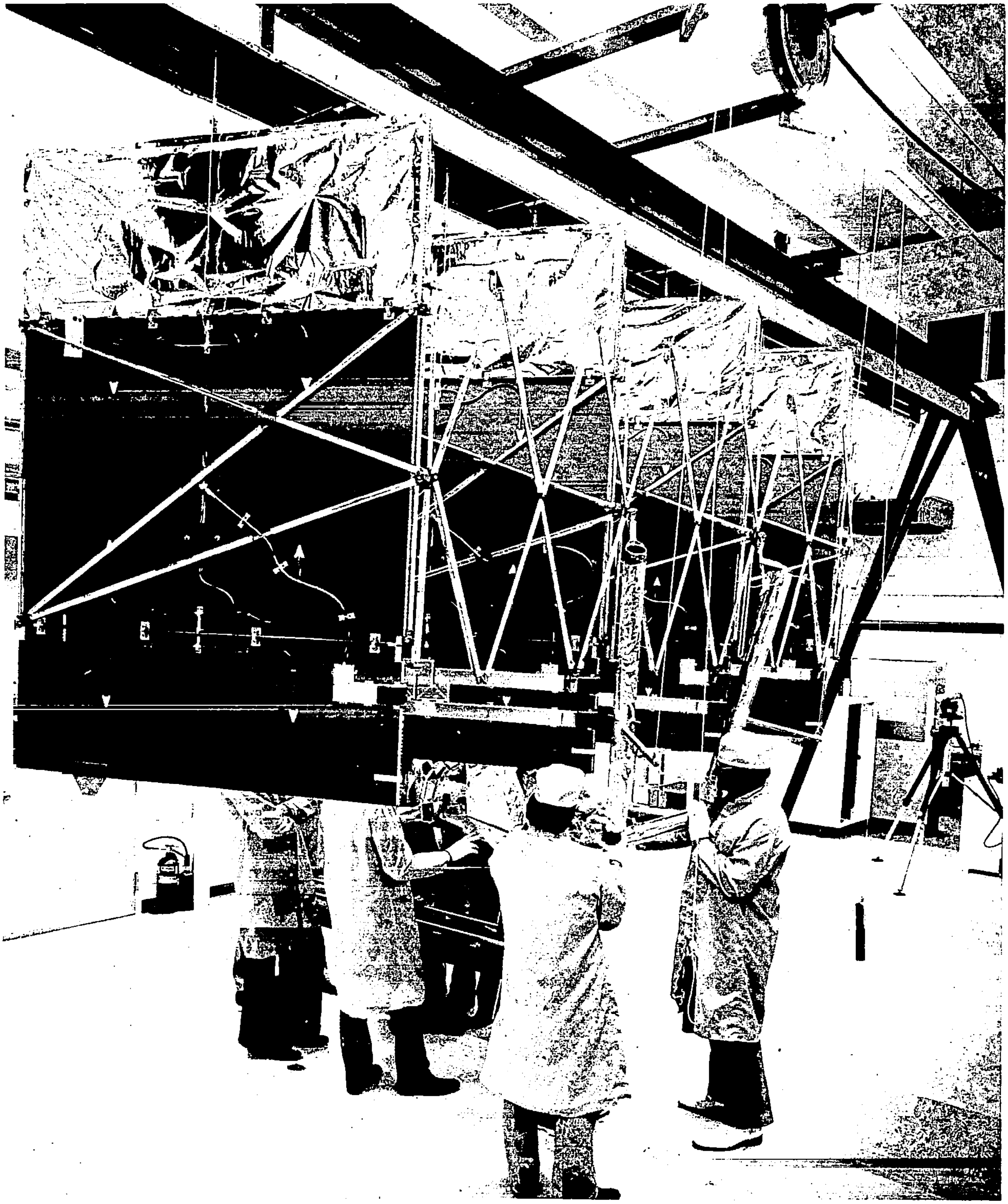

Fig. 9. SAR Partially Deployed.

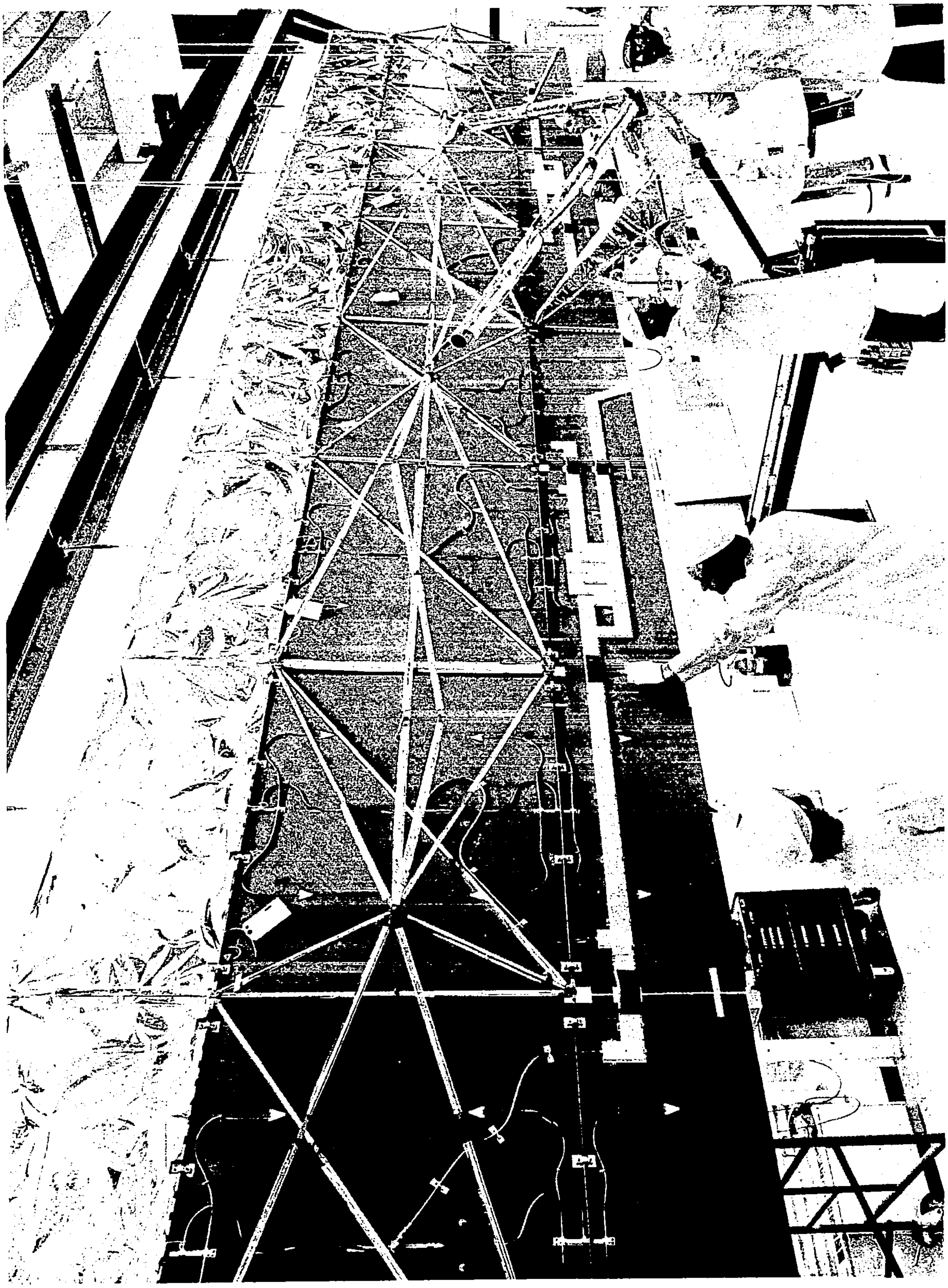

Fig. 10. SAR Deployed.